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Basic role of medical ventilators to lower COVID-19 fatality and face next pandemic crises

By Mario COCCIA †

Abstract. In the presence of global pandemic crisis of the Coronavirus Disease 2019 (COVID-19), although some countries have experienced high levels of infections, they have lower numbers of COVID-19 related deaths. Why? This exploratory research here analyzes the vital role of technological innovation of medical ventilators to cope with the initial stage of COVID-19 pandemic without specific pharmaceutical treatments (drugs and vaccines). Results suggest that countries having a high number of medical ventilators (26.76 per 100,000 inhabitants) have in general a fatality rate lower (1.44% in December 2020) than countries with low average number of medical ventilators (10.38 per 100,000) that have a high fatality rate of 2.46% in the same period. These findings bring us to suggest a technology -oriented strategy of preparedness to cope with future pandemic threats based on high levels of R&D investments in healthcare sectors with new infrastructures, skilled human resources and especially modern technologies of high-tech medical ventilators that can reduce negative effects of emerging infectious diseases when specific drugs and treatments lack.
Keywords. COVID-19 pandemic; Coronavirus Disease 2019, Artificial ventilation; Mechanical ventilation, Noninvasive ventilation, New technology; Crisis management; Pandemic preparedness; Hospital Ventilators; Health emergencies.
JEL. H12; H51; I10; O14; O32; O33.

1. Introduction

In the presence of new infectious diseases generating pandemic crisis, such as Coronavirus Disease 2019 (COVID-19), countries apply health policies based on varying degrees of containment measures having the objective to mitigate and/or stop transmission dynamics of infections and consequently reduce the numbers of deaths (Anttiroiko, 2021; Coccia, 2022; Nicoll & Coulombier, 2009; Vinceti et al., 2021). Although a high degree of restrictions and high levels of vaccination to reduce the risk factors of COVID-19 infections, many countries have experienced high numbers of deaths, such as Italy, Central and South America countries, etc. (Coccia, 2021, 2021a, 2022). High negative impact of COVID-19 pandemic in society is due to manifold factors, such as new variants, high air pollution and density of people in cities, intensive commercial activities of countries, low investments in healthcare sectors, etc. (Bontempi et al., 2021; Bontempi & Coccia, 2021). However, some countries have experienced high levels of infections, but they have lower numbers of COVID-19 related deaths. The goal of the study here is to explain this main problem by focusing on critical role of technology to cope with COVID-19 crisis and reduce mortality in society when new drugs lack. In particular, the idea here is to find evidence, with an exploratory research, whether countries having a high number of medical ventilators in the initial stage of COVID-19 pandemci crisis, they have also experienced lower fatality

† CNR, National Research Council of Italy & Yale University School of Medicine, 310 Cedar Street, Lauder Hall, Suite 118, New Haven, CT 06520, USA.

rates than countries with poor equipment of medical technologies. Findings can support a different strategy of preparedness for the next stage of the COVID-19 pandemic and future pandemics that should be not focused on restriction policies but on modern infrastructures, skilled human resources, high R&D investments in drug discovery , and new medical technologies that can reduce high numbers of deaths and support socioeconomic systems.

2. Theoretical framework

In the context of COVID-19 pandemic crisis, a main technology to cope with a serious respiratory disorder of patients admitted in Intensive Care Units (ICUs) is mechanical ventilator, which is applied to patients with acute or acute-on-chronic respiratory failure that do not respond to standard therapeutic interventions, such as administration of antibiotics, bronchodilators. etc. (Cabrini et al., 2015). Mechanical ventilator is an artificial breathing device that is used for patients that are not able to breathe naturally due to a critical illness, such as COVID-19 (Gong et al., 2021). Hu et al. (2021) argue that ventilators in the intensive care units (ICU) are life-support devices that help physicians to gain additional time to cure the patients. Medical ventilators can be:

- stationary devices for ICUs.
- mobile devices with external battery used to transfer patients within and between hospitals, for in-home use, etc.

In addition, medical ventilations can be:

- Invasive, which involves endotracheal intubation.
- Non-invasive (NIV), involving various types of face masks.

New technology provides flexible and mobile medical ventilators for adults, children and newborns (Dräger, 2022).

Many patients are intubated and ventilated invasively into trachea to provide appropriate levels of oxygen and initiate lung healing (IMARC, 2022). However, invasive ventilation can create problems to lung and infections in case of prolonged utilization, such as to treat COVID-19 patients (Chandrasekaran and Monikandan, 2021). Side effects of invasive devices are ventilator-associated lung injury, alveolar overdistension that leads to inflammatory processes and fluid accumulation, ventilator-associated pneumonia, etc. (cf., Gosangi et al., 2022; Ma et al., 2022). Non-Invasive Ventilation (NIV) is a new technology invented in the 1987 that can reduce ventilator-associated lung injury and other health problems (Lobato & Alises, 2013; Pierson, 2009). The use of NIV (e.g., helmet and facemask) has increased over the past two decades, and now this new technology is an integral tool in the patient management having both acute and/or chronic respiratory failure, at home and ICUs (Saxena et al., 2022; Soo Hoo, 2020, 2010). Technological advances of NIV allow to accurately measure patient's airway pressure, moreover the respiratory abdominal sensor and transducer allow patient-triggered pressure assists with breath rate monitoring (Medtronic, 2022). In addition, new technology of NIV allows an adequate humidification to maintain airway clearance, optimize ventilation and improve patient comfort (similarly to normal functions of the nose and air passages of the respiratory tract that are to warm, moisten and filter the inhaled gases before they reach the lungs; cf., WILAmed, 2022; Maheshwarappa et al., 2021). Weerakkody et al. (2022) argue that the superiority of non-invasive ventilation also over highflow nasal oxygen in reducing the need for intubation with low reported complications. Zhang et al. (2022) show that early adoption of non-invasive ventilation can improve the health of patients with severe COVID-19. Chandrasekaran & Monikandan (2021) maintain the therapeutic advantages of the integration of oxygen helmet with negative pressure ventilator in patients exposed to various ventilator-induced lung injuries, such as barotrauma, etc. Overall, then, NIV in patients with COVID-19 is safe, cost- effective, improves resource utilization, and can be associated with better outcomes but studies are needed to address timing of intervention, validation of oxygenation indices, and inflammatory markers as predictors of treatment success of this technology (Auld et al., 2020; Lee et al., 2020; Weerakkody et al., 2022).

The major countries producing medical ventilators for ICUs are in table 1 with the name of leading companies.

Table 1. *Top global countries producing medical ventilators*

Company Name	Headquarters Location	Country
Airon Corporation	Melbourne, Florida	USA
Becton Dickinson and Company	Franklin Lakes, NJ	USA
Bio-Med Devices, Inc.	Guilford, CT	USA
Bunnell Incorporated	Salt Lake City, UT	USA
Cardinal Health	Dublin, OH	USA
GE Healthcare	Chicago, IL	USA
Hartwell Medical Corp.	Carlsbad, CA	USA
Hillrom	Chicago, IL	USA
Vyaire Medical Inc.	Chicago, IL	USA
Oceanic Medical Products, Inc.	Atchison, KS	USA
ResMed Corp.	San Diego, CA	USA
United Hayek Industries, Inc.	San Diego, CA	USA
Ventec Life Systems	Bothell, WA	USA
Hamilton Medical	Bonaduz	USA/Switzerland
ACUTRONIC Medical Systems AG	Hirzel	Switzerland
Smiths Group	London	UK
Medtronic	Dublin	Ireland
Air Liquide Healthcare	Paris	France
Getinge AB	Göteborg	Sweden
aXcent medical	Koblenz	Germany
Drägerwerk AG	Lübeck	Germany
Löwenstein Medical Innovation	Kronberg	Germany
Dima Italia	Bologna	Italy
Philips	Amsterdam	The Netherlands
Avasarala Technologies Limited	Bengaluru	India
Aeonmed co., ltd.	Beijing	China
Mindray Medical International	Shenzen	China
Triton Electronics Systems, Ltd.	Yekaterinburg	Russia
Fisher & Paykel	Auckland	New Zealand

Source: Müller (2020); Edwards (2022)

Table 1 shows that the USA and Germany have many top medical ventilator manufacturers. In particular, global market has leading ventilator companies that establish the overall structure of this industry (in parentheses the firms with the highest market share in 2019, cf., Müller, 2020): Hamilton Medical (22%), Getinge (22%), Draeger (16%), Minday (10%), Medtronic (5%), Philips (3%), Vyaire Medical (3%), Becton Dickinson, Fisher & Paykel Healthcare, GE Healthcare, and Smiths Group. In the presence of pandemic crisis some countries, such as Germany had a high number of medical ventilators: about 30,000 units in 2020 (Our World in Data, 2022). Although Germany has a population of more than 83 million, COVID-19 deaths are lower than other countries having a smaller level of total population (The World Bank, 2022; Johns Hopkins Center for System Science and Engineering, 2022). Overall, then, the role of this technology of medical ventilators to cope with negative effects of COVID-19 in society has critical aspects and deserves to be examined to support a comprehensive strategy of preparations to face next pandemics of unknown respiratory disorders when new drugs and other pharmaceutical interventions lack. Next section presents the methodology to investigate this critical problem.

3. Study design

3.1. Sample

The sample is based on all 9 countries for which data of medical ventilators are available (Our World in Data, 2022). Countries of the sample here are: Canada, France, Germany, New Zealand, Norway, South Korea, Switzerland, United Kingdom, United States.

3.2. Measures for statistical analyses

- Medical ventilators. Ventilators, total number over time span: 2015 – 2020). Source: Our World in Data (2022).
- Degree of strictness of health policies. Containment and Health Index is based on thirteen indicators of government responses by countries to face COVID-19 pandemic, such as school closures, workplace and business closures, quarantines, domestic and international travel reductions, cancellation of public and private events, vaccination policies, etc. This index has a range from 0=min to 100=max level of restrictions and strictness (Hale et a., 2021). Average values of Containment and Health Index over January 2020 - January 2022 period (Stringency Index, 2022).
- Vaccination is measured by percent share of people fully vaccinated against COVID-19 on 14 February 2022. Source: Our World in Data (2022a).
- Wealth of nations. Gross domestic product (GDP) is the value added created through the production of goods and services in a country in a specific period. This study considers GDP per capita in 2020, constant 2010US$ (The World Bank, 2022a).
- Health expenditure (% of GDP). It includes healthcare goods and services consumed during a certain year. Period 2008-2018 (last year available). The Word Bank (2022b).
- Population total of the year 2020 based on all resident people. Source: The World Bank (2022b).
- Mortality is measured with Case Fatality Ratio (CFR) %. It assesses the impact of COVID-19 in society and the quality of healthcare system because a lower CFR suggests fewer negative effects on health of people and also a better effectiveness of healthcare system (Coccia, 2021a; Lau et al., 2021; WHO, 2020; Wilson et al., 2020). Case Fatality Ratio (CFR) is given by:

$$Case\ Fatality\ Ratio\ \text{(CFR) \%}=\left(\frac{Number\ of\ deaths\ from\ COVID-19}{Number\ of\ confirmed\ cases\ of\ COVID-19}\right)\times 100$$

Angelopoulos at al. (2020) maintain that Case Fatality Ratio (CFR) between countries is a critical indicator to support governments in the decision making to cope with COVID-19 pandemic crisis.

CFR is considered on 31 December 2020, before the COVID-19 vaccination to consider the effective role of medical ventilators on health system, when this technology was the only approach to treat the new infectious disease of COVID-19 because effective drugs lacked.

CFR is also considered on 21 February 2022 after the vaccination, when the role of medical ventilator should be reduced because of the introduction of new drug to treat COVID-19, such as vaccines. Source of data: Johns Hopkins Center for System Science and Engineering (2022).

3.3. Data analysis procedure

Firstly. Total number of medical ventilators are divided by total population of counties and presented per 100,000 inhabitants. After that, the sample is divided in two sets considering the average values of 15 medical ventilators per 100,000 people:

- Group 1: Countries with a high level of medical ventilators per inhabitants: value higher than 15 ventilators per 100,000 people
- Group 2: Countries with a low level of mechanical ventilators per inhabitant ventilators: value lower than 15 ventilators per 100,000 people

Secondly. Descriptive statistics is given by arithmetic mean (M) and standard deviation (SD) of variables for comparative analysis of the effectiveness of this technology to cope with COVID-19 pandemic, considering average fatality rate before and after the introduction of vaccinations in just mentioned groups (cf., Coccia, 2018).

Thirdly. The study applies the Independent Samples T-test to determine whether there is statistical evidence that the arithmetic means of variables between groups are significantly different and that countries having a high level of medical ventilators per inhabitants, they have also lower numbers of COVID-19 related deaths. Considering the small sample, the robustness of parametric test (Independent Samples T-test) is also checked with the Kruskal-Wallis H test: it is a rank-based nonparametric test used to determine if there are statistically significant differences between two groups of an independent variable on a continuous dependent variable (fatality rates %).

4. Results and discussions

Descriptive statistics of ventilators per 100,000 people in two groups mentioned in methods is:

- Countries with a high level of medical ventilators: average ventilators per 100,000 people over 2015-2020 (last year available) =26.76 (SD=14.94)
- Countries with a low level of medical ventilators: average ventilators per 100,000 people over 2015-2020 (last year available) =10.38 (SD=2.57)

Table 2. *Descriptive statistics*

	Countries with LOW numbers of ventilators, N=4		Countries with *HIGH* numbers of ventilators, N=5	
Description of variables	M	SD	M	SD
Medical ventilators per 100,000 inhabitants, 2015-2020	10.38	2.57	26.76	14.94
Containment Index over 2020-2022 period	57.60	4.29	53.58	7.21
Fully vaccinated % against COVID-19, February 2022	73.00	4.24	70.50	5.97
GDP per capita in 2020, U$	52,093.27	19,156.84	51,196.42	24,067.16
Health expenditure % of GDP, 2008-2018	10.96	0.80	10.95	3.68
Fatality rates %, 31 December 2020 (§)	2.460	0.561	1.436	0.412
Fatality rates %, 21 February 2022	0.77	0.28	0.55	0.47

Note: M= arithmetic mean; SD=Standard Deviation; (§) this value is important to assess the real effect of medical ventilator on the health of people because it is produced before the implementation of strategies of vaccination in countries.

Table 2 shows a main finding: countries having high average number of medical ventilators per 100,000 people (M=26.76, SD=14.94), they have low average fatality rates of 1.43% (SD=0.41) on December 2020 compared to countries with low average number of medical ventilators (M=10.38, SD=2.57) having a higher average fatality rate (M=2.46%, SD=0.56) in the same period. These results are in a homogenous socioeconomic framework because GDP per capita in 2020 and average health expenditure % of GDP (2008-2018) in two sets is almost similar. Moreover, countries with a high average number of medical ventilators per 100,000 people, compared to countries with a low equipment of this technology, they have low average fatality rates in a context of health policy with a lower degree of strictness and also low percent share of people fully vaccinated against COVID-19. This result has important aspects because studies suggest that a high strictness of compulsory measures can deteriorate the socioeconomic systems(cf., Barro, 2020; Goolsbee and Syverson, 2021).

Figure 1 shows that countries with a high average number of medical ventilators per 100,000 people, they have low average fatality rates (1.46%), also with a lower percent share of people fully vaccinated against COVID-19 compared to countries with low technological equipment of medical ventilators (Atkeson, 2021).

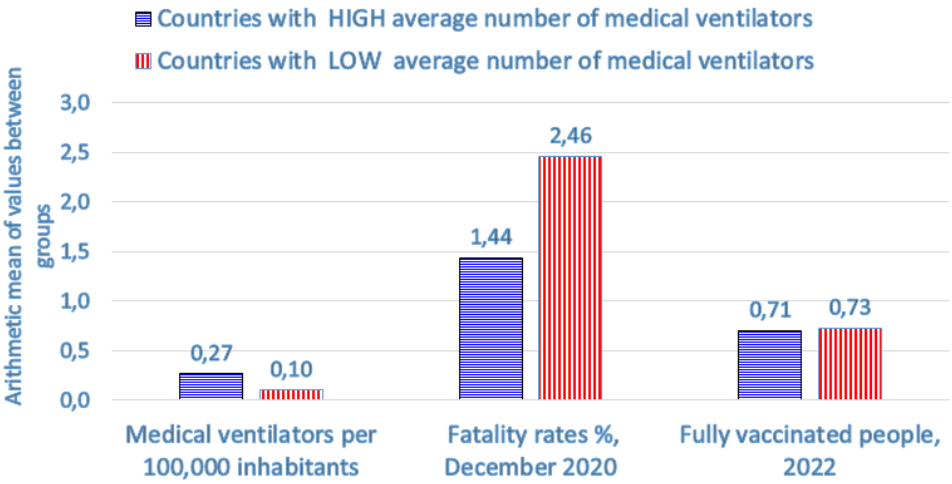

Figure 1. *Comparative analysis of technological, mortality and health indicators between countries with high and low level of ventilators*

Table 3. *Independent Samples T-Test of countries with high vs. low numbers of medical ventilators per 100,000 inhabitants between countries*

		Levene's Test for equality of variances		*T*-test for equality of Means				
		F	Sig.	*t*	df	Sig. 2-tailed	Mean Difference	Std. Error Difference
Log Medical ventilators per 100,000 inhabitants, 2015-2020 (#)	•Equal variances assumed	6.499	0.038	-2.904	7	0.023	-0.852	0.293
	•Equal variances not assumed			-3.144	5.959	0.020	-0.852	0.271
Fatality rates %, 31 December 2020 (§)	•Equal variances assumed	0.161	0.701	3.164	7	0.016	1.024	0.324
	•Equal variances not assumed			3.046	5.395	0.026	1.024	0.336
Fatality rates %, 21 February 2022	•Equal variances assumed	3.319	0.111	0.822	7	0.438	0.220	0.267
	•Equal variances not assumed			0.874	6.563	0.413	0.220	0.251

Note: # Log transformation is to have a normal distribution of the variable within two sets. (§) this value is important to assess the real effect of medical ventilators on the health of people because it is produced before the implementation of strategies of vaccination in countries.

Independent Samples T-test in table 3 shows a significant difference of the arithmetic means of fatality rate at 31 December 2020 (before the introduction of COVID-19 vaccines) between groups of countries with high and low numbers of medical ventilators (p-value 0.05); the difference of average fatality rates between just mentioned groups (though the mean is lower in countries with high equipment of medical ventilators) is not significant at February 2022 because the widespread and pervasive diffusion of vaccinations (an innovation to treat COVID-19) in these countries (more than 70% people vaccinated) has reduced the fruitful effects of this technology.

Table 4. *Kruskal-Wallis Test of countries with high vs. low numbers of medical ventilators per 100,000 inhabitants*

	Ranks		
		N	Mean Rank
Medical ventilators per 100,000 inhabitants, 2015-2020	LOW number of medical ventilator per 100,000 people	4	2.5
	HIGH number of medical ventilator per 100,000 people	5	7.0
	Total	9	
Fatality rates %, 31 December 2020	LOW number of medical ventilator per 100,000 people	4	7.0
	HIGH number of medical ventilator per 100,000 people	5	3.4
	Total	9	
Fatality rates %, 21 February 2022	LOW number of medical ventilator per 100,000 people	4	5.75
	HIGH number of medical ventilator per 100,000 people	5	4.4
	Total	9	

Kruskal-Wallis Test Statistics-a, b

	Medical ventilators per 100,000 inhabitants, 2015-2020	Fatality rates %, 31 December 2020	Fatality rates %, 21 February 2022
Chi-Square	6	3.84	0.54
df	1	1	1
Asymp. Sig.	0.014	0.05	0.462

Note: a) Kruskal Wallis Test; b) Grouping Variable

Table 4 shows Kruskal-Wallis H test, a rank-based nonparametric test, which confirms previous results and statistically significant difference of fatality rates in December 2020. In particular, Kruskal-Wallis H test shows that:

- there was a statistically significant difference in medical ventilators between different groups $\chi2(1) = 6.00$, p-value = 0.01, with a mean rank score of 2.5 for countries with LOW number of medical ventilator per 100,000 people and 7 for countries having HIGH number of medical ventilator per 100,000 people.
- there was a statistically significant difference in fatality rates in December 2020 between different groups having a high/low level of medical ventilators $\chi2(1) = 3.85$, p-value = 0.05, with a mean rank score of 7 for countries with LOW number of medical ventilator per 100,000 people and 3.4 for countries having HIGH number of medical ventilator per 100,000 people.
- As explained for Independent sample T-test, the differences of fatality rate in February 2022 between groups is insignificant for the role of the innovation of new vaccines that have mitigate the differences between countries to cope with COVID-19 and reduced the mortality in countries with low numbers of medical ventilators but high level of vaccination.

In general, the statistical evidence above seems in general to support that a high equipment of medical ventilators (during the initial phase of pandemic crisis when vaccines and/or antivirals to treat unknown respiratory disorders of COVID-19 lack) plays a strategic role to improve the preparedness and resilience of countries and mitigate the negative effects (mortality) of pandemic in society. Since the impact of next pandemic will be determined by how well-prepared countries are when it occurs at any time with little warning, and how countries timely respond and are prepared with their infrastructure and technologies, study here suggests that high numbers of medical ventilation is a basic aspect to reinforce healthcare and to treat people with respiratory infections of new viruses when drugs lack.

These findings suggest a different strategy of crisis management for future pandemic threats, a strategy that is not based on strict policies of containment, but it is technology oriented with high levels of R&D investments in healthcare sector and in particular in modern technologies that really improve the preparedness of countries to cope with pandemic crisis and reduce negative effects of high numbers of COVID-19 related deaths in society (Coccia, 2021). In general, in contexts of pandemic threats of airborne infectious diseases, nations have to invest in different types of medical ventilators to prepare healthcare sector also considering the increase of other respiratory diseases, such as chronic obstructive pulmonary disease (COPD) associated with high air pollution in cities, high number of people affected of diabetes, hypertension and cardiovascular diseases, the growth of geriatric population, and the increase in tobacco consumption worldwide. The medical ventilator market shows that the segment of non-invasive ventilators is growing at a rapid pace because this new technology has fewer side effects (e.g., ventilator-associated pneumonia, lung injury, and barotrauma) and faster recovery of patients. Moreover, technological advancements of medical ventilator (e.g., the development of mobile and non-invasive mechanical ventilators, high-speed signal processing system, higher efficiency and safety measures of the equipment to make them flexible for different age group of patients --pediatric, adult, geriatric-- and finally cost-effective devices) are driving the diffusion between countries. Studies show that the UK has applied policy responses with low strictness, but fatality rate of COVID-19 is similar or lower than countries with more restrictions (Ball, 2021; Birch, 2021; Kufel et al., 2022; Johns Hopkins Center for System Science and Engineering, 2022; Kargi et al., 2023, 2023a; Uçkaç et al., 2023, 2023a). One of the factors is that the UK has high R&D investments, and it has produced one of the first vaccines to cope with COVID-19 with the collaboration between University of Oxford and AstraZeneca company with the funding support from UK Research and Innovation and Medical Research Councils (UKRI, 2022). Moreover, the UK has one of the top ventilator companies in the world: Smiths Group, founded in 1851 with the Smiths Medical that specializes in infusion therapy, artery access, and critical care, as well as other specialized goods and services. Their systems are used in critical and intensive care, surgery, post-operative care, and for assistance in treating serious disease in hospitals, emergency rooms, homes, and specialized healthcare providers (Smiths Medical, 2022). An interesting case study of the effectiveness of medical ventilators to cope with initial phases of COVID-19 is also Germany having very high numbers of confirmed cases on population given by 21.16% (on 15 March 2022) but the fatality rate is low (0.71%) compared to other countries (Johns Hopkins Center for System Science and Engineering, 2022). Germany has one of the highest percentages of medical ventilators per 100,000 people worldwide and has also a lot of top ventilator companies having a large market share, such as aXcent medical, Dräger and Löwenstein Medical Innovation, which have supported the healthcare system with high-tech technological devises during the initial phases of COVID-19 crisis, minimizing the pandemic impact (mortality) in society (Dräger, 2022; Löwenstein Medical Innovation, 2022).

These findings bring us to suggest an appropriate strategy of crisis management focused on high levels of investments in healthcare sector to support new infrastructures, skilled human resources and new technology given by high-tech medical ventilators that improve the preparedness of countries to cope with future pandemic threats, in particular considering that the drug discovery process to treat effectively unknown infectious diseases need months or years to generate innovation in markets.

5. Conclusions remarks

In the presence of a global pandemic threat, one of the goals of nations is to mitigate mortality and support economic growth (cf., Coccia, 2021b). Studies analyze different policy responses of non-pharmaceutical interventions to cope with the spread of COVID-19 but their effectiveness to mitigate negative effects of infections and deaths in society is uncertain (Askitas et al., 2021; Flaxman et al., 2020). The dynamics and effects of COVID-19 pandemic are due to a variety of factors associated with environment, good governance, investments in healthcare goods and services, new technology, IT and stocks of vaccines and antiviral drugs for emergencies, etc. (Allen, 2022; Barro, 2020; Coccia, 2021a, 2021b; Goolsbee and Syverson, 2021; Homburg, 2020; Wieland, 2020). The findings here suggest a different strategy of crisis management for future pandemic threats, not based on strict policies of containments but technology oriented and focused on high levels of investments in healthcare sectors and in particular in R&D investments in drug discovery and modern technologies of medical ventilator noninvasive that support the preparedness and resilience of countries to face pandemic threats but also to face the increasing incidence of chronic respiratory diseases (e.g., chronic obstructive pulmonary disease-COPD, asthma, bronchitis, and other lung disorders, etc.), the growth of smoking population and geriatric population prone to respiratory emergencies. In fact, a main factor of preparedness of pandemic crisis is constant investments in health system that reinforce and prepare healthcare infrastructure with new technologies to emergency, when effective drugs lack, in order to mitigate mortality, morbidity and stress among the population (Kluge et al., 2020; Coccia, 2022a, 2022b, 2022c). Coccia (2021a) reveals that countries with lower COVID-19 fatality rates have a high average level of health expenditure given by 7.6% of GDP and average government health expenditure per capita of about $2,300, whereas countries with higher fatality rates of COVID-19 have an average health expenditure of 6% of GDP and very low government health expenditure per capita. Other scholars, such as Kapitsinis (2020), argue that investments in health sector are the foundations to prepare countries for emergencies and mitigate mortality rate of COVID-19 (Ardito et al., 2021).

The results of this analysis here seem to be that countries with a high number of medical ventilators have a lower fatality rate of COVID-19 than countries with low equipment of these technological devices, though they have a similar level of health expenditure, individual wellbeing (GDP per capita) and of full vaccinated people. This finding brings us to maintain that the high equipment of new medical technologies and in general of effective national system of innovation in countries play a critical role to cope with pandemic impact, emergencies and environmental threats. These conclusions are of course tentative. There is need for much more research in these topics because not all the possible confounding factors that affect the fatality rates and mortality between countries are taken into consideration and in future studies new factors deserve to be investigated for supporting results here (cf., Angelopoulos et al., 2020). Results here have also to be reinforced with a much more follow-up investigation based on a large sample of countries for additional analyses of the relations between technology of medical ventilators, response policies, dynamics and effects of pandemic impact on health of people and socioeconomic system.

To conclude, Ball (2021) argues that the diversity of pandemic outcomes and responses throughout the world makes it hard to draw any general conclusions about how science, technology, government, and society interact in contexts of pandemic crisis management (cf., Shattock et al., 2022). However, the findings here propose a general strategy of crisis management for future pandemic threats: little restrictions, transparent and consistent communication of rules, and especially high levels of investments in healthcare sector focused on new technology of noninvasive medical ventilators to support the preparedness of countries with appropriate technology-oriented strategies, rather than strictness-oriented policies to cope with future pandemic threats by reducing overall negative effects on health of people and also socioeconomic system.

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